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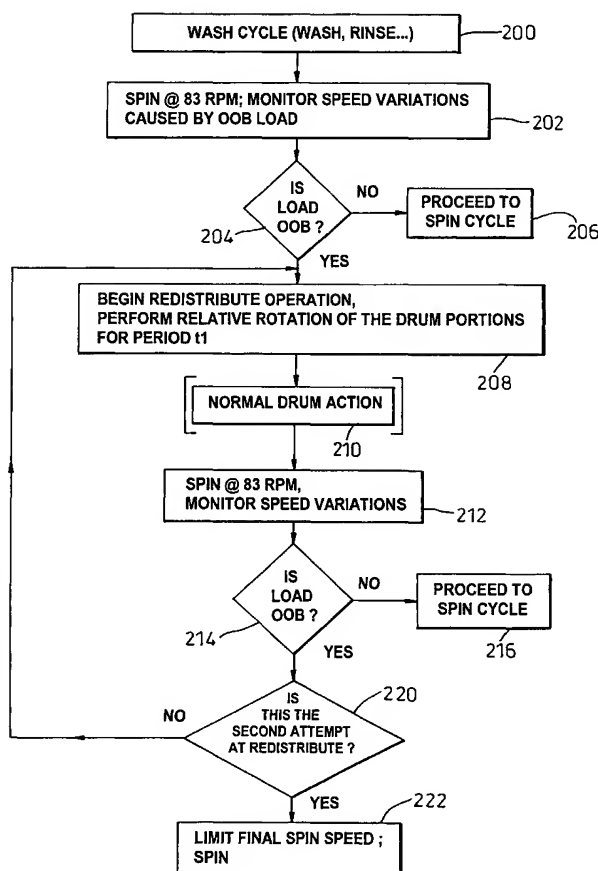
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(54) Title: LAUNDRY APPLIANCE



(57) Abstract: A laundry appliance, such as a washing machine, comprises a drum for receiving a load of articles to be laundered. The drum comprises at least two rotatable drum portions and a drive which can rotate the drum portions relative to one another. A controller causes the appliance to perform a laundering cycle which includes a spin cycle in which the drum is rotated at high speed. Before the spin cycle, the controller detects whether there is an imbalance of the load in the drum and, in the event of an imbalance, the controller causes the appliance to redistribute the load by causing the drive rotate the drum portions relative to one another. In the event of a continued imbalance, the controller can repeat the redistribute operation or it can limit the spin speed during the spin cycle.

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**Laundry Appliance**

The present invention relates to a laundry appliance such as a washing machine or washer-dryer.

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Washing machines perform a washing cycle which usually includes a period in which the drum of the machine is rotated at a high spin speed to dry the clothes held within the drum. There is a demand for washing machines which can operate at a high spin speed, since a high spin speed results in drier clothes which require less drying time after they have been removed from the machine. A high spin speed also reduces the length of the spin cycle which is required for a given water extraction from clothing. Washing machines are currently available which can spin at speeds of up to 1800 rpm.

In order that the washing machine can operate at high spin speeds, the drum/tub assembly must be well engineered and more importantly the load inside the drum should be uniformly distributed around the inner circumferential wall of the drum. If the load is not uniformly distributed around the drum, an out-of-balance mass is present which will cause rotational and translational vibrations of the drum when the drum is rotated. Such vibrations cause unwanted noise and other undesirable effects such as machine "walking" and also increases stresses on the drive system for the drum. Under extreme out-of-balance conditions, large drum displacements can result in the drum striking the tub within which it is housed, resulting in noise and possibly damage to the machine. The nature and size of the load within the drum, and the manner in which the user has loaded the drum can significantly affect the balance of the drum at the end of the wash cycle.

Many washing machines are arranged to perform a distribution cycle at a relatively low drum rotational speed of around 83rpm between the end of the rinsing cycle and the beginning of the spin cycle. The distribution cycle aims to evenly distribute the rinsed clothes before the spin cycle.

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Washing machines are known which include some form of system which, after the distribution cycle, monitors whether the load is adequately balanced or whether there is an out-of-balance condition. This prevents damage to the machine. If the machine determines that the load within the drum is out-of-balance then it attempts to redistribute the load. One way of redistributing the load is to perform a brief wash action, i.e. a tumble and counter-tumble, before performing another distribution cycle. Another known way of redistributing the load is to introduce water into the drum to remove the clothes from the wall of the drum, to rotate the drum and then to extract the water again in the hope that the clothes will now be better distributed. However, this is often ineffective and is wasteful of water. When a machine fails to adequately redistribute the load within the drum, it may often proceed to the spin cycle and spin the load at a reduced speed, which results in clothes being inadequately dried and dissatisfaction for the user.

The present invention seeks to provide a more effective manner of redistributing a load within the drum.

Accordingly, a first aspect of the invention provides a laundry appliance comprising a drum for receiving a load of articles to be laundered, the drum comprising at least two rotatable portions and a drive capable of rotating the drum so as to cause relative rotation between the adjacent rotatable portions, and a controller for causing the appliance to perform a laundering cycle which includes a spin cycle in which the drum is rotated at high speed, wherein, before the spin cycle, the controller is arranged to detect whether there is an imbalance of the load in the drum and, in the event of an imbalance, the controller causes the appliance to redistribute the load by causing the drive to perform relative rotation of the portions of the drum.

The step of performing relative rotation of the drum portions has the advantage in that it can more effectively redistribute the load within the drum compared with other known methods. This is because the relative rotation of the drum portions has a shearing action

on clothes which have come to rest against the wall of the drum. The relative rotation of the drum, aided by paddles on the drum, if they are fitted, helps to release the clothes from the wall of the drum. It also helps to separate a wet mass of rinsed clothes whereas the conventional tumbling action tends to roll clothes together. This should  
5 allow the load to distribute itself more evenly and more quickly. It also achieves redistribution of the load without using water, and thus is more economical.

Preferably, the portions of the drum are rotated in opposite directions at the same or different speeds. Alternatively, each of the portions of the drum can be rotated at a  
10 different speed in the same direction.

Further aspects of the invention provide a controller for the appliance and a method of operating the appliance.

15 Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is an overall cross-sectional view of a washing machine;

20 Figure 2 shows the control system for the machine of Figure 1;

Figures 3 shows operation of the drum of the machine of Figure 1 during counter-rotating operation;

25 Figure 4 is a flow diagram of a method performed by the control system of Figure 2 for controlling the machine of Figure 1.

Figure 1 shows a washing machine 10 which includes an outer casing 12 in which a stationary tub 40 is located. A drum 50 is mounted inside the tub 40 so as to be  
30 rotatable about an axis 85. The tub 40 is watertight except for an inlet 21 and outlet 22. The washing machine 10 includes a soap tray 20 capable of receiving detergent in a

known manner. At least one water inlet 23 communicates with the soap tray 20 and is provided with suitable means for connection to a water supply within the environment in which the washing machine 10 is to be used. A conduit 21 is provided between the soap tray 20 and the tub 40 so as to allow water introduced via the inlet 23 to enter the tub 40. The tub 40 has a sump 26 located beneath the drum 50. A drainage pipe 28 communicates with the sump 26 and leads to a water outlet 30 via which water can be discharged from the washing machine 10. A pump 42 is provided to allow water to be pumped from the sump 26 to the water outlet 30 at appropriate stages of the washing cycle carried out by the washing machine 10.

The drum 50 is rotatably mounted about the axis 80 by way of a shaft 80. The shaft 80 is mounted in a known manner, allowing the tub 40 to remain stationary whilst the drum 50 is rotatable with the shaft 80. The shaft 80 is rotatably driven by a motor (not shown) mounted within the outer casing 12 of the washing machine 10. A door 66 is located in the front panel 12a of the outer casing 12 to allow access to the interior of the drum 50. It is via the door 66 that a wash load can be deposited within the drum 50 before a wash cycle commences and removed from the drum 50 at the end of the wash cycle.

Drum 50 comprises two portions 60, 70 which are mounted such that they can be rotated with respect to one another. A drum of this type is described more fully in International Patent Application WO99/58753. Typically the drum portions 60, 70 are rotated in opposite directions to one another, i.e. one portion clockwise, one counter-clockwise, but they can also be rotated together in the same direction. The drum 50 is mounted in a cantilever fashion on the wall of the tub 40 remote from the door 66. The first outer rotatable portion 60, is supported on a hollow cylindrical shaft 81. An angular contact bearing 82 is located between the rear wall of the tub 40 and the hollow cylindrical shaft 81. The outer rotatable portion 60 is dimensioned so as to substantially fill the interior of the tub 40. More specifically, the outer rotatable portion 60 has a generally circular rear wall 63 extending from the hollow cylindrical shaft 81 towards the cylindrical wall of the tub 40, a generally cylindrical wall 564 extending generally

parallel to the cylindrical walls of the tub 40 from the rear wall 63 towards the front wall of the tub 40, and a generally annular front face 64 extending from the cylindrical wall 61 towards the door 66. Sufficient clearance is allowed between the walls 61, 63, 64 of the outer rotatable portion 60 and the tub 40 to prevent the outer rotatable portion 60 from coming into contact with the tub 40 when the drum 50 is made to spin.

An inner cylindrical wall 62 is also provided on the interior of the cylindrical wall 61 of the outer rotatable portion 60. The inner cylindrical wall 62 extends from a point which is substantially midway between the rear wall 63 and the front face 64 to the front face 64. The space between the interior cylindrical wall 62 and the cylindrical wall 61 is hollow but, if desired, could be filled with a strengthening material. In this event, the strengthening material must be lightweight. The provision of parallel cylindrical walls 61, 62 in the portion of the outer rotatable portion 60 closest to the front face 64 provides strength to the whole of the outer rotatable portion 60 whilst reducing the internal diameter of the outer rotatable portion 60 in this region.

The inner rotatable portion 70 is supported on a central shaft 80, which in turn, is supported by deep groove bearings 83 located between the central shaft 80 and the hollow cylindrical shaft 81. The inner rotatable portion 70 essentially comprises a generally circular rear wall 71 extending from the central shaft 80 towards the cylindrical wall of the tub 40, and a cylindrical wall 74 extending from the periphery of the rear wall 71 towards the front wall of the tub 40. The diameter of the cylindrical wall 74 of the inner rotatable portion 70 is substantially the same as the diameter of the inner cylindrical wall 62 of the outer rotatable portion 60. The cylindrical wall 74 of the inner rotatable portion 70 is dimensioned so that its distal end approaches the end of the cylindrical wall 62 closest to it. It is advantageous to keep the gap between these two cylindrical walls 62, 74 as small as possible. An annular sealing ring 76 is located on the cylindrical wall 61 of the outer cylindrical portion 60 immediately adjacent to the end of the inner cylindrical wall 62 closest to the inner cylindrical portion 70 so as to provide support for the distal end of the cylindrical wall 76 thereof. The central shaft 80 and the hollow cylindrical shaft 81.

Figure 2 shows a control system for the machine 10. A controller 100 operates according to a control program stored on a non-volatile memory 105. The controller 100 is preferably implemented in the form of a microcontroller but other ways of implementing the controller, such as an implementation entirely in hardware, will be apparent to the reader and are intended to fall within the scope of this invention. An interface 110 interfaces the controller 100 to other parts of the machine 10. Sensors placed on the machine return input signals to the interface 110. The sensors include a sensor which monitors the value of the mains supply voltage and a tacho T which monitors the speed of the motor M. Motor M has an output drive shaft which is connected via a drive belt to a drive wheel and a gearbox to rotate the portions 60, 70 of the drum 50 about axis 85. The interface 110 also connects to a control panel 120 which is mounted on the front face of the machine 10. Control panel 120 includes switches 121, 122 (among others) by which a user can select a wash programme, wash temperature, spin speed, special functions etc., indicator lamps 123, 124 to confirm a user's selections or to indicate error conditions, and a display panel 125, such as an LCD display, on which text messages can be displayed to prompt the user or to inform the user of the progress of the machine during the wash cycle. Interface 110 receives inputs from the control panel to allow the controller 100 to determine what switch 121, 122 a user has pressed and outputs control signals to illuminate the indicator lamps 123, 124 and display 125. The interface also outputs a set of control signals 140 to control the operating state of various parts of the machine, such as the door lock, water inlet valves, and motor M. In a well-known manner, the control software 105 controls operation of the machine according to the inputs it receives and issues outputs 160 for controlling various parts of the machine. The signal from tacho T is indicative of the actual speed of the drum and is used by the controller to determine when the load inside the drum is out-of-balance.

The speed of motor M is controlled on the basis of an actual motor speed input to the interface and a speed demand, and an output signal 145 controls motor drive 130. Control signal 145 controls the firing angle of the triac (or other power switching



device) in the motor drive circuit 130. Another output signal 144 controls the direction of rotation of the motor M and a further output signal 146 controls the state of the gearbox. The state of the gearbox determines whether the drum portions 60, 70 are rotated in unison or whether they are rotated relative to one another. Motor M can be used to drive both drum portions 60, 70 or two separate motors may be provided, one motor being used to drive each of the drum portions 60, 70.

Figure 3 shows the portions 60, 70 of the drum 50 counter-rotating with respect to one another about the rotational axis 85.

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Figure 4 is a flow diagram of a method performed by the controller 160 to control operation of the machine 10. Firstly, at step 200, the machine performs the usual washing and rinsing operations of a wash cycle. There may be several of each of these operations. At the end of the wash cycle rinse water is pumped from the drum while the drum slowly rotates. The drum then performs a distribute operation (step 202) in which the drum is rotated at a speed of around 83rpm. This should distribute the load more evenly within the drum. Controller 160 monitors the resulting speed at which the drum actually rotates. At this distribute speed the drum speed varies over the course of a cycle; the drum speed decreasing as the motor which drives the drum struggles to lift the out-of-balance mass and then increasing as the drum is accelerated due to gravity aiding the falling out-of-balance mass.

The signal from the drum rotation speed monitor returns a waveform that includes a useful component that represents speed of the drum, plus a noise component. Therefore, a simple inspection of the amplitude of the waveform would not yield a true indication of the speed of drum rotation. An approximate root-mean-square (RMS) method takes samples of the amplitude every quarter drum revolution (which corresponds to several revolutions of the drum due to gearbox reduction) over a number of cycles. If y0 is the first data point, then y1 is at 90° drum rotation, y2 is at 180°, y3 is at 270° and y4 is at 360° (the first point on the next wave.) Two running sums of

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difference are required for the RMS calculation as below (in this example y11 is the last data point:

$$\text{Sum1} = (y_0 - y_2) - (y_2 - y_4) + (y_4 - y_6) - (y_6 - y_8) + (y_8 - y_{10})$$

$$5 \quad \text{Sum2} = (y_1 - y_3) - (y_3 - y_5) + (y_5 - y_7) - (y_7 - y_9) + (y_9 - y_{11})$$

Dividing the sums by two gives the following simplifications, which are used in the software:

$$10 \quad \text{Sum1} = \frac{1}{2}y_0 - y_2 + y_4 - y_6 + y_8 - \frac{1}{2}y_{10}$$

$$\text{Sum2} = \frac{1}{2}y_1 - y_3 + y_5 - y_7 + y_9 - \frac{1}{2}y_{11}$$

At the end of the sample period, the value of the out-of-balance is given by

$$15 \quad \text{Resulting OOB} = (\text{Sum1})^2 + (\text{Sum2})^2$$

At step 204 the machine determines if the load is sufficiently balanced. The result of the calculation made above is compared with a threshold value representing an acceptable value of OOB. If the load is judged to be sufficiently balanced, the machine progresses to operate at a higher spin speed (step 206). If the load is judged to not be sufficiently balanced then a redistribute operation occurs (step 208). During this time the drum portions 60, 70 are driven in such a way that relative rotation occurs between them. The relative rotation occurs for a time period t1, which is typically 15s, but other time periods may be desirable. After this time period the machine may perform normal drum rotation, with both drum portions 60, 70 being rotated in the same direction at the same speed (step 210) or it may move straight to a monitoring operation at distribute speed. The machine again monitors balance of the load at distribute speed. Controller 160 monitors the resulting speed at which the drum actually rotates. If the load is judged to be sufficiently balanced, the machine progresses to operate at a higher spin speed (step 216). If not, a determination is made (step 220) if this is the second attempt at redistribute. If two attempts at redistribute have occurred, without success, the

controller 160 limits the final spin speed of the drum 50 (step 222). If only one attempt at redistribute has occurred, the controller progresses to a second redistribute cycle. Clearly, the controller can be arranged to perform any other number of attempts at redistributing the load before progressing to the spin cycle.

**Claims**

1. A laundry appliance comprising a drum for receiving a load of articles to be laundered, the drum comprising at least two rotatable drum portions and a drive capable  
5 of rotating the drum so as to cause relative rotation between the adjacent rotatable drum portions,  
and a controller for causing the appliance to perform a laundering cycle which includes a spin cycle in which the drum is rotated at high speed,  
wherein, before the spin cycle, the controller is arranged to detect whether there is an  
10 imbalance of the load in the drum and, in the event of an imbalance, the controller causes the appliance to redistribute the load by causing the drive to perform relative rotation of the drum portions.
2. An appliance according to claim 1 wherein, after the period in which the drum is  
15 driven with relative rotation between the portions of the drum, the controller is arranged to cause the drive to rotate the drum in a normal manner, with both portions substantially rotating together.
3. An appliance according to claim 1 or 2 wherein the controller is arranged to  
20 detect an imbalance of the load in the drum by rotating the drum at a speed at which the load is held against the wall of the drum and monitoring variations in speed indicative of an imbalance condition.
4. An appliance according to any one of the preceding claims wherein the  
25 controller is arranged to detect whether there is an imbalance following the redistribute operation and, in the event of a continued imbalance, to repeat the redistribute operation.
5. An appliance according to any one of the preceding claims wherein the  
30 controller is arranged to detect whether there is an imbalance following the redistribute

operation and, in the event of a continued imbalance, to limit the spin speed during the spin cycle.

6. An appliance according to any one of the preceding claims wherein the controller causes the portions of the drum to rotate in opposite directions.

7. An appliance according to any one of the preceding claims wherein the controller causes the portions of the drum to rotate at different speeds.

8. An appliance according to any one of the preceding claims in the form of a washing machine.

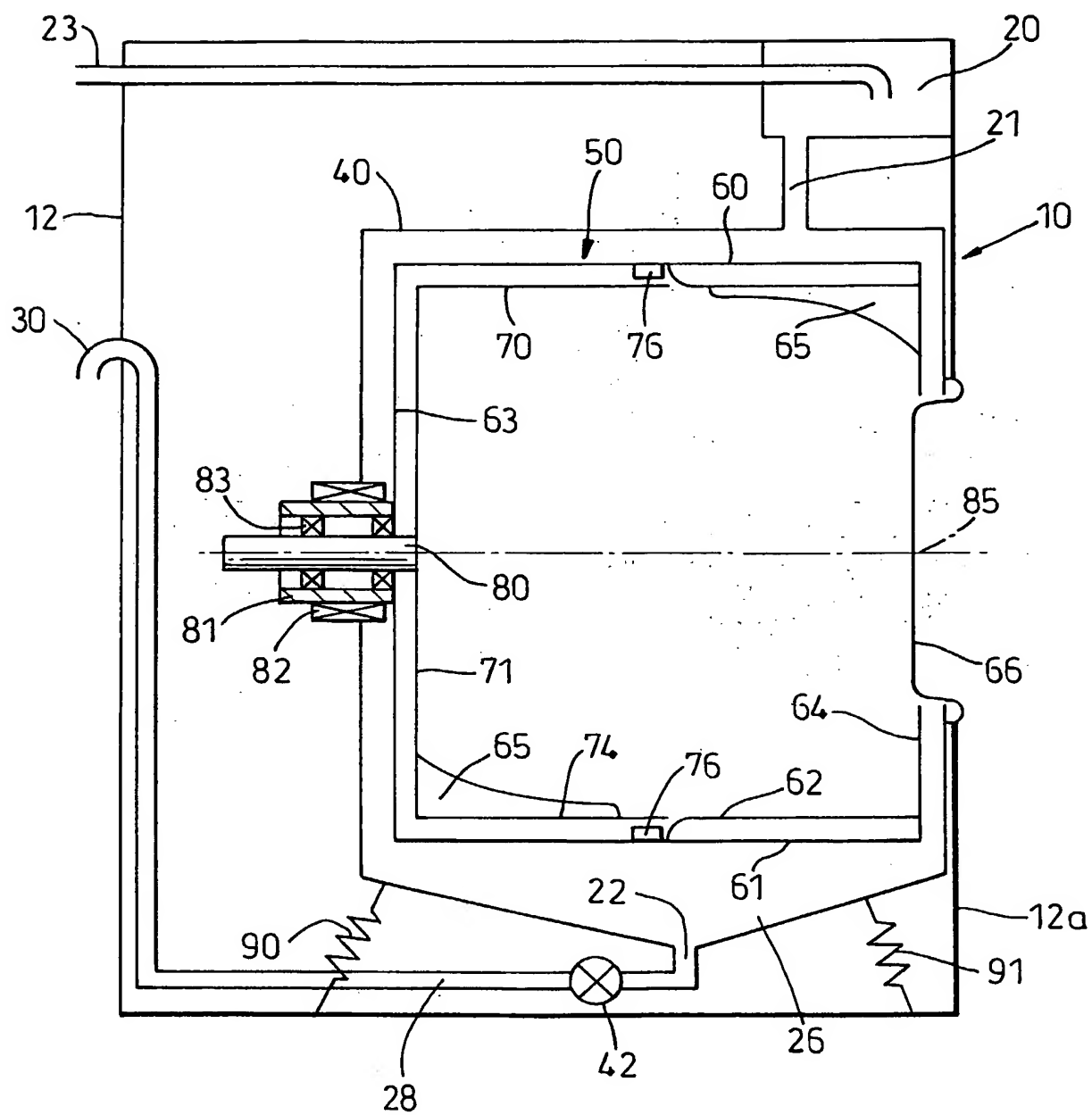
9. A controller for a laundry appliance, the appliance comprising a drum for receiving a load of articles to be laundered, the drum comprising at least two rotatable drum portions and a drive capable of rotating the drum so as to cause relative rotation between the adjacent rotatable drum portions, the controller being arranged to cause the appliance to perform a laundering cycle which includes a spin cycle in which the drum is rotated at high speed, and wherein, before the spin cycle, the controller is arranged to detect whether there is an imbalance of the load in the drum and, in the event of an imbalance, the controller causes the appliance to redistribute the load by causing the drive to perform relative rotation of the drum portions.

10. A method of operating a laundry appliance, the appliance comprising a drum for receiving a load of articles to be laundered, the drum comprising at least two rotatable drum portions and a drive capable of rotating the drum so as to cause relative rotation between the adjacent rotatable drum portions, and a controller for controlling the appliance, the method comprising, the controller causing the appliance to perform a laundering cycle which includes a spin cycle in which the drum is rotated at high speed, and, before the spin cycle, the controller detecting whether there is an imbalance of the load in the

drum and, in the event of an imbalance, the controller causing the appliance to redistribute the load by causing the drive to perform relative rotation of the drum portions.

- 5 11. A laundry appliance, a controller for a laundry appliance or a method of operating a laundry appliance substantially as described herein with reference to the accompanying drawings.

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*Fig. 1*

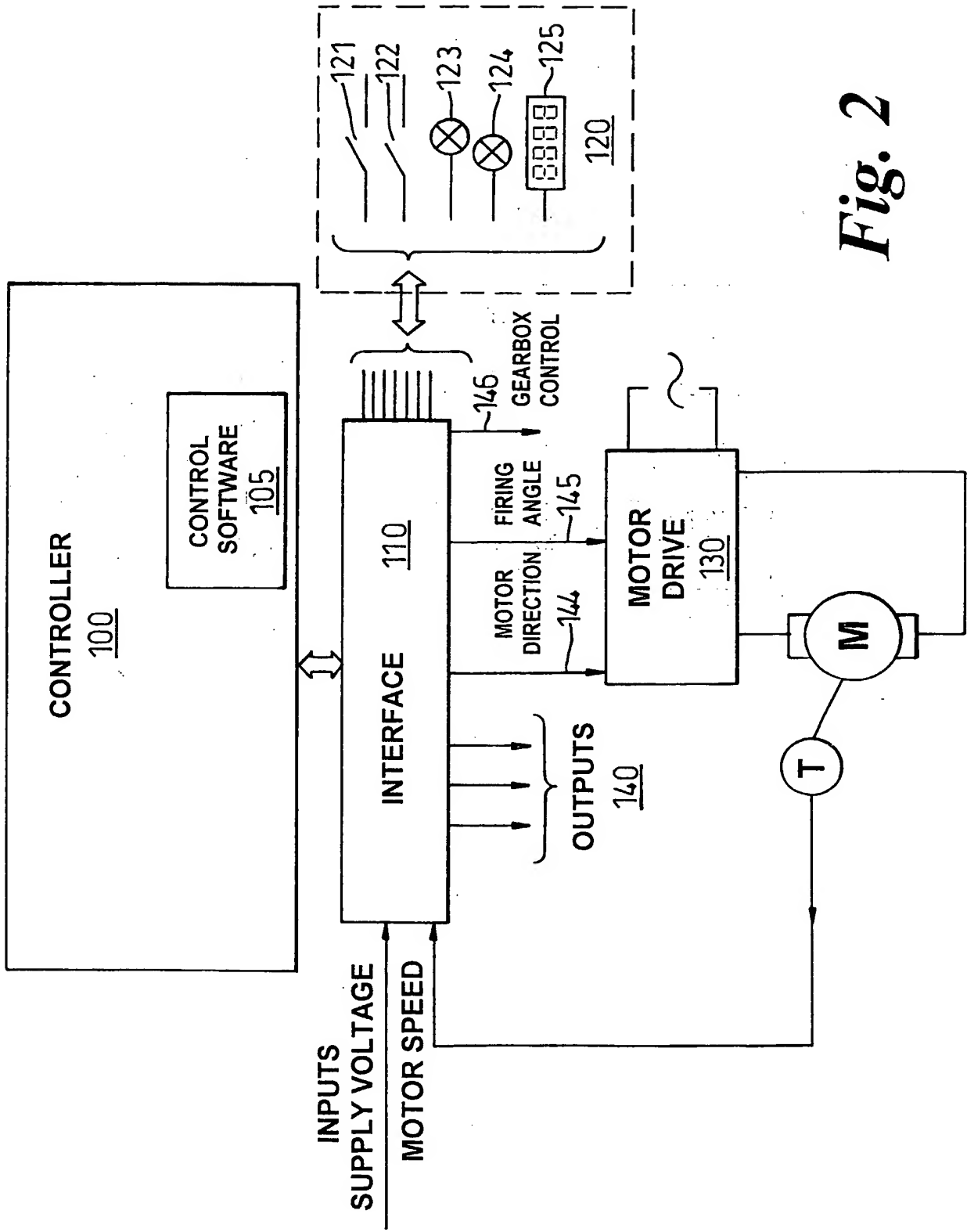
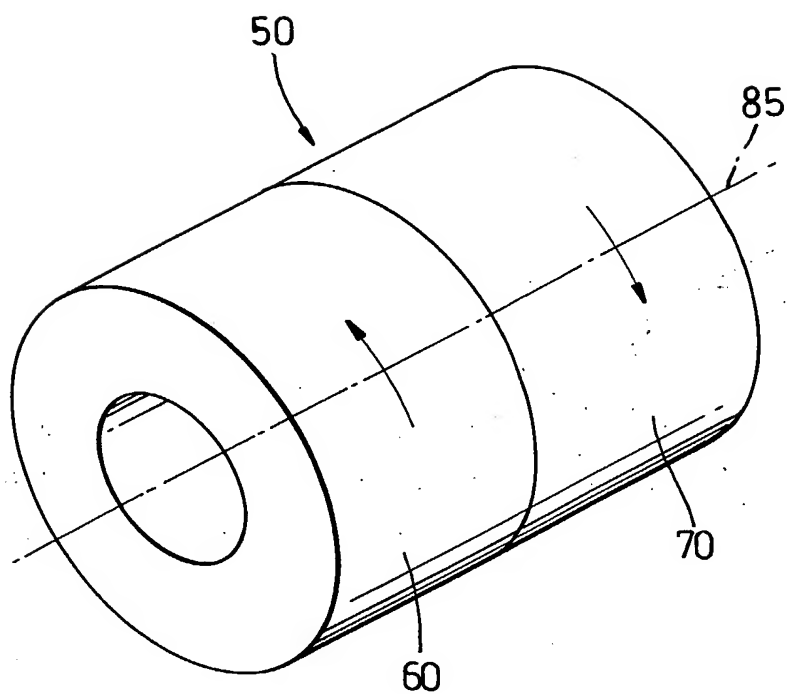


Fig. 2

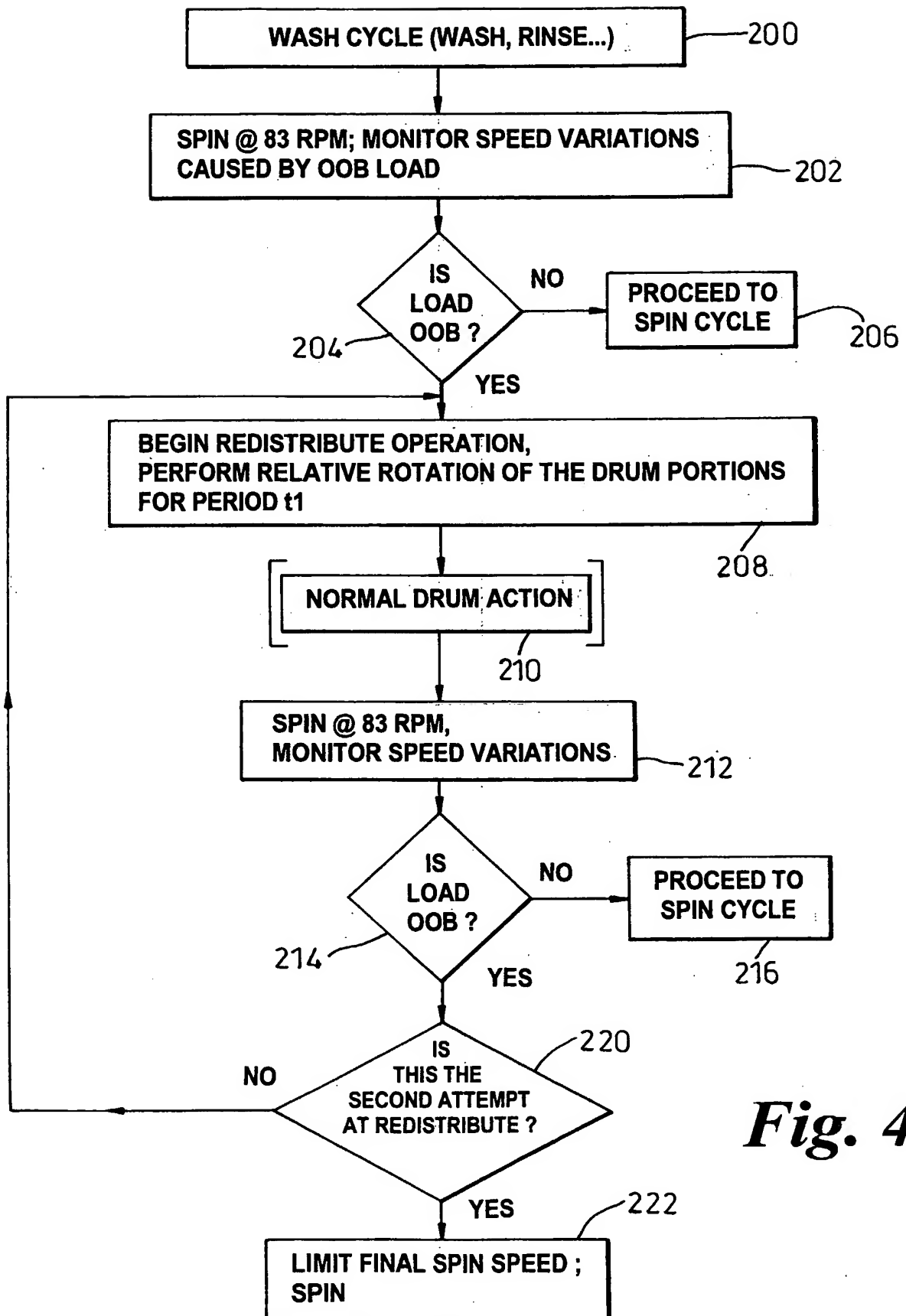


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***Fig. 3***

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*Fig. 4*